P800 780/DE/1

PCT

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F01N 3/28, 3/02, F02M 25/07

A1

(11) International Publication Number: WO 99/09307

(43) International Publication Date: 25 February 1999 (25.02.99)

(21) International Application Number: PCT/GB98/02408

(22) International Filing Date: 10 August 1998 (10.08.98)

(30) Priority Data:
9717034.4 13 August 1997 (13.08.97) GB

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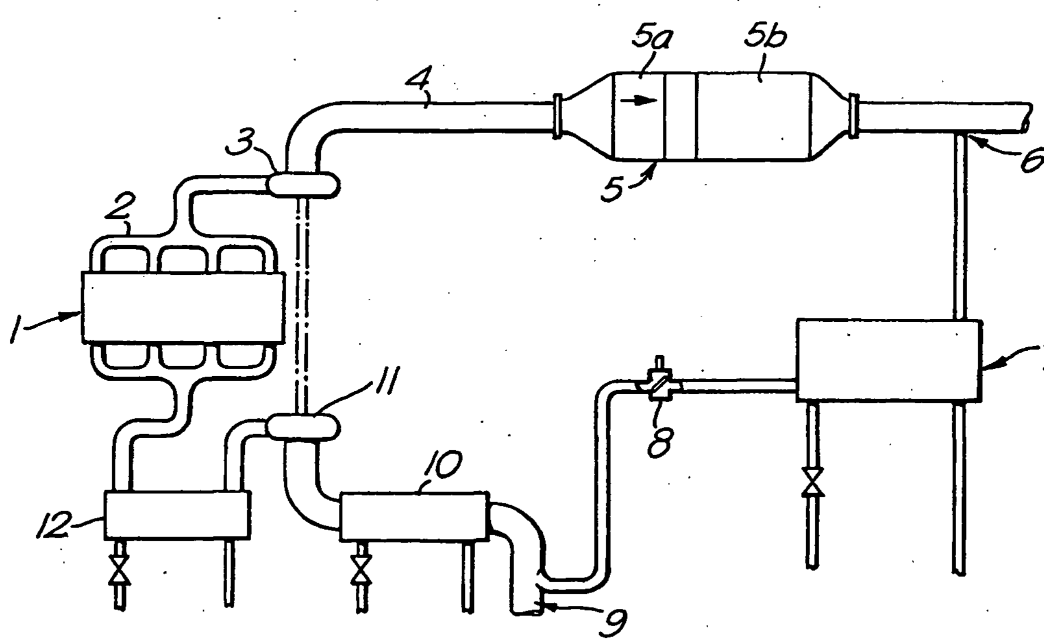
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: IMPROVEMENTS IN EMISSIONS CONTROL



(57) Abstract

A heavy duty diesel engine (1) has an exhaust system incorporating a catalyst (5a) to convert NO to NO_2 and a particulate trap (5b) on which soot particles are continuously oxidised, and a portion of the cleaned gases are recirculated through a cooler (7) and an exhaust gas flow valve (8) before being mixed with air and fed to the engine cylinders. Considerable reductions in NOx can be achieved.

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IMPROVEMENTS IN EMISSIONS CONTROL

The present invention concerns improvements in emissions control. More especially, the invention concerns improvements in the control of NOx from diesel engines.

The use of emission control catalysts for engine exhaust clean-up is well established. Diesel engines have different characteristics from gasoline-fuelled engines, with a different mix of pollutants caused by the different fuels, the different combustion characteristics in each engine and the lower temperatures met with in exhausts from diesel engines. Additionally, diesel engines emit more noticeable particulates, especially under heavy load and upon start-up, than gasoline engines. In general, it can be said that diesel engines emit less NOx than a gasoline engine under most conditions, but because diesel engines mostly or exclusively operate on a high air to fuel ratio, that is are "lean"-burn engines, the chemistry of the exhaust gas does not favour NOx reduction, because of the excess of oxidising species.

To meet the various emission regulations already or about to enter force, it has become necessary to treat diesel exhausts in various ways. Oxidation catalysts, which catalyse the oxidation of unburnt hydrocarbons ("HCs") and carbon monoxide ("CO") are now regularly fitted to light duty diesels, and particulate traps of various types are becoming commonplace on heavy duty diesels as used in trucks, buses and some stationary engines. A technique for improving exhaust gas emissions, especially NOx emissions from diesel engines is exhaust gas recirculation ("EGR"), which takes a proportion of the exhaust gas and recirculates it into the engine cylinders. Generally, about 30 to 60vol% of the exhaust gases are recirculated, depending upon the characteristics of the particular engine and the emission limits which must be met. Although EGR has been used with gasoline engines for about ten years, it has only been more recently fitted to diesel engines; we believe that most vehicles currently fitted with EGR are passenger car light duty diesel engines. In the case of engines fitted with a catalyst, the exhaust gas is always taken from upstream of the catalyst. It is generally expected that EGR would have a significant effect on emissions from heavy duty diesel engines, that is those fitted to heavy trucks and buses. Because of the engineering problems caused by the very different exhaust characteristics compared to light

duty diesel engines, however, this has proved difficult to achieve. In particular, there is no commercial source of an EGR valve of suitable size and materials to be fitted to a heavy duty diesel engine.

We refer also to a device marketed as the "CRT" by Johnson Matthey PLC. This device is described in US Patent No 4,902,487 and is a continuously regenerative particulate trap. Unlike the vast majority of particulate traps, however, this device regenerates *in situ* without the need for periodic replacement or electrical heating to ignite the soot. Such device relies upon a catalyst system which generates NO_2 which we found is effective to cause low temperature combustion of trapped soot particles.

The principle of the CRT has been adopted by Hino in their published Japanese patent applications JP 8338320 and JP 9088727, in combination with EGR. However, such systems as described are not believed to be capable of use in true heavy duty diesel applications.

We have surprisingly found that a novel diesel engine system can offer very low levels of NOx. The present invention provides a diesel engine system comprising a diesel engine and an exhaust system therefor, characterised in that the exhaust system incorporates a catalyst effective to convert NO to NO_2 under normal operating conditions, a trap for particulates mounted downstream of the catalyst and an exhaust gas recirculation system mounted downstream of the trap and cooling means to cool the portion of exhaust gas which is recirculated.

The invention also provides a process for the reduction of NOx in diesel engine exhaust gases, comprising, in order, converting at least a portion of the NO in the gases to NO_2 by passing the gases over a catalyst, trapping at least the majority of carbonaceous particles in the gases on a trap and continuously oxidising said particles and cooling and recirculating at least a portion of the cleaned gases leaving the trap, to the engine cylinders.

The exhaust gas recirculation may be carried out using essentially well established technology, using valves in the exhaust system and a control system. It is believed that the present invention may be operated most effectively at a lower recirculation ratio (*eg* 5 to 30% by vol) than is normal. Although engine intake vacuum may provide adequate EGR, it may be preferable to provide pumping to provide a vacuum using a variable speed fan or pump operating under the control of the engine management unit.

The catalyst and trap may be as described in USP 4,902,487 or as practised in the commercial Johnson Matthey CRT device. A preferred trap is an extruded ceramic, *eg* cordierite, wall flow filter.

It is to be realised that since only a portion of the exhaust gases is recycled, the system and process of the invention may be operated in one embodiment so that such a portion of the exhaust gases leaving the engine is treated by the catalyst and trap and all the treated portion is recirculated. The remainder of the exhaust gases is passed into a conventional exhaust system which may desirably contain a separate catalyst and trap combination.

The present invention is believed to offer, in its preferred embodiments, certain unexpected advantages. The invention, because it does not depend upon a reduction catalyst reaching light-off temperature, is effective to reduce NOx at all engine operating temperatures. Additionally, traditional EGR systems suffer from wear and other degradation both of the EGR valves which are used to extract the recirculating portion of the exhaust gases, and on engine or exhaust components themselves. Such degradation may lead to expensive rebuilds, and a system that offers the potential for savings in this area has considerable economic value. In particular, the reduction in soot provides relatively clean gas for the cooling means. The main benefit of this is the maintenance of good heat exchange compared to a heavily sooted cooling means, but other consequences include reduced servicing requirements.

In accordance with the principles of the present invention, the skilled person may adapt the invention to different diesel engines and in different ways achieve the benefits of the invention.

The present invention is illustrated with reference to the accompanying schematic drawing of one embodiment of the invention.

A heavy duty diesel engine is generally indicated by 1. The engine exhaust manifold, 2, connects to a turbine, 3, and feeds into an exhaust system, 4. A standard commercial Continuous Regenerating Trap, 5, obtainable from Johnson Matthey PLC, Royston, England, is fitted in the exhaust system, and includes a catalyst element, 5a, and a filter element, 5b. Mounted downstream of the CRT, is a simple T-junction pipe, 6, which can extract a portion of cleaned exhaust gas, according to the status of the exhaust flow valve described below. The portion of exhaust gas is passed to an exhaust gas cooler, generally indicated by 7, which is effective to reduce the temperature of the exhaust gas to the range 80 to 150°C. The exhaust gas cooler may be a liquid-cooled device, as shown in the drawing, or air cooled. The cooled gas then passes through an exhaust gas flow valve, 8, which is actuated under the control of an engine management unit (not shown). According to the position of the valve (in the particular test reported below, shut = no EGR, fully open = 30% EGR), exhaust gas is extracted through pipe 6 for recirculation. The engine management unit utilises conventional sensing to determine suitable load conditions for EGR operation, for example at idle and up to about half load conditions, including acceleration, but the use of EGR under full load conditions is not presently expected to be advantageous.

The exhaust gas is then blended with fresh air for combustion taken through an air intake, 9. Desirably an inter-cooler unit, 10, cools the combustion air and recycled exhaust gas to about 25 to 40°C before it is compressed by a turbocharger unit, 11, driven by a shaft from the turbine, 3. The charge of gas is then passed through the standard inter-cooler unit, 12, to cool the gas to about 35 to 60°C before it is fed to the engine.

The invention will also be described for illustrative purposes only in the following Example.

EXAMPLE

A heavy duty 10 litre diesel bus engine (manufactured by Volvo) was used for a series of tests, using the configuration shown in Figure 1.

The reduction of NOx at the tailpipe, relative to the normal output of the engine, was plotted on Figure 2 at various EGR rates. (The prototype valve could not be closed entirely and even in the nominally fully closed position provided about 1% EGR. It can readily be seen that even at 5% EGR, there is an approximately 15% reduction in tailpipe NOx emissions. At EGR rates of 25 to 30%, the reduction of NOx is 80 to 90% or more. Use of EGR does, however, incur a fuel penalty shown in a broken line on Figure 2. Beyond 30% EGR, this penalty becomes unacceptable.

The results shown in Figure 2 represent 50% load (585Nm) at an intermediate speed (1450 rpm), which is equivalent to ECE Regulation 49 mode #4.

Further tests were carried out under different load/engine speed combinations according to the various modes of ECE R-49. In all cases there was a considerable and unexpected reduction in NOx, increasing with EGR rate. The system tested was not optimised, yet promises NOx reductions of 70% or more. It is believed that a conventional EGR, operating at much higher EGR rates than in the present invention, *eg* 30 to 50%, does not offer NOx reductions greater than 60%.

CLAIMS

1. A diesel engine system comprising a diesel engine and an exhaust system therefor, characterised in that the exhaust system incorporates a catalyst effective to convert NO to NO_2 under normal operating conditions, a trap for particulates mounted downstream of the catalyst, an exhaust gas recirculation system mounted downstream of the trap and cooling means for the portion of exhaust gas that is recirculated.

2. A system according to claim 1, wherein said exhaust gas recirculation system comprises a valve and a control system therefor, and the cooling means is mounted upstream of the valve.

3. A system according to claim 1 or 2, wherein the exhaust gas recirculation ratio is adjustable in the range 5 to 30% by vol according to the position of the valve.

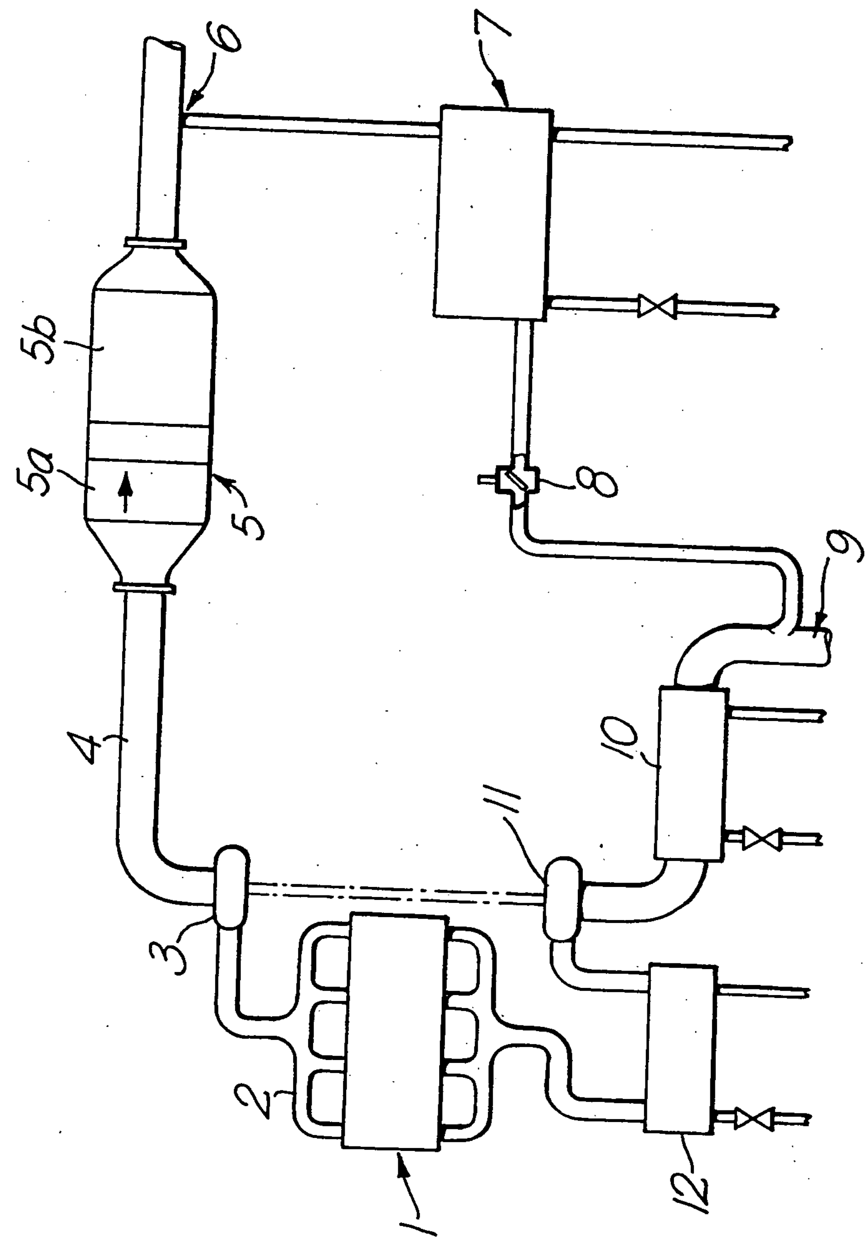
4. A system according to claim 1, 2 or 3, wherein a pump is incorporated in the exhaust gas recirculation system, said pump operating under the control of an engine management system.

5. A system according to any one of the preceding claims, wherein the diesel engine is a heavy duty diesel engine.

6. A process for the reduction of NOx in diesel engine exhaust gases, comprising, in order, converting at least a portion of the NO in the gases to NO_2 by passing the gases over a catalyst, trapping at least the majority of carbonaceous particles in the gases on a trap and continuously oxidising said particles and cooling and recirculating at least a portion of the cleaned gases leaving the trap to the engine cylinders.

7. A process according to claim 7, wherein the quantity of exhaust gas recirculated is in the range 5 to 30% by vol.

8. A process according to claim 7 or 8, wherein the portion of exhaust gas recirculated is cooled before it meets an exhaust gas recirculation valve.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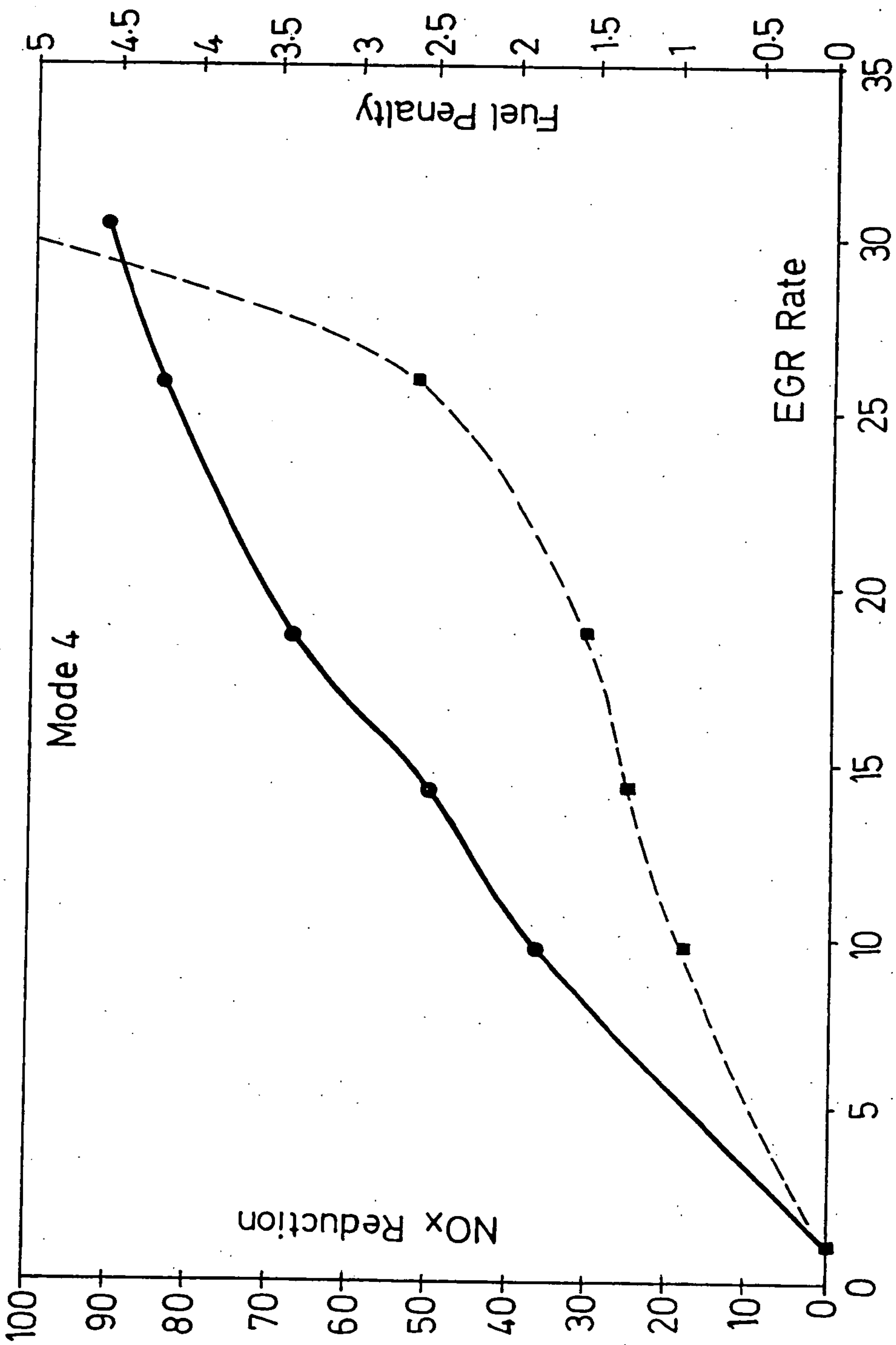
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NOx Reduction
EGR Rate
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/02408

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01N3/28 F01N3/02 F02M25/07

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F01N F02M

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 902 487 A (JOHNSON MATTHEY INC) 20 February 1990 cited in the application see column 1, line 66 - column 2, line 52 see column 3, line 21-35 see column 3, line 52 - column 4, line 5 see figure 1 ---	1,2,6,8

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[X] Further documents are listed in the continuation of box C.

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26 November 1998

Date of mailing of the international search report
08/12/1998

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Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DATABASE WPI Section Ch, Week 9710 Derwent Publications Ltd., London, GB; Class H06, AN 97-104299 XP002085831 & JP 08 338320 A (HINO MOTORS LTD) , 24 December 1996	1,2,6,8
A	see abstract & PATENT ABSTRACTS OF JAPAN vol. 97, no. 4, 30 April 1997 & JP 08 338320 A (HINO MOTORS CO), 24 December 1996 see abstract; figure 9 -----	5

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Information on patent family members

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PCT/GB 98/02408

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4902487 A	20-02-1990	AT 132940 T	15-01-1996
		DE 68925382 D	22-02-1996
		DE 68925382 T	15-05-1996
		DK 233389 A	14-11-1989
		EP 0341832 A	15-11-1989
		ES 2081301 T	01-03-1996
		GR 3018800 T	30-04-1996
		IE 71167 B	29-01-1997
		JP 1318715 A	25-12-1989